DEPARTMENT OF COMMERCE
CIVIL AERONAUTICS ADMINISTRATION
WASHINGTON

CIVIL AERONAUTICS
MANUAL 04-T

# TRANSPORT CATEGORY REQUIREMENTS

NOVEMBER 1, 1944

## CONTENTS

# PREFACE

## PURPOSE

The basic purpose of this Manual is to identify all of the Civil Air Regulations which apply specifically to the Transport Category and therefore distinguish it from all other categories, as well as to interpret these regulations in an effort to:

(1) explain the purposes intended to be accomplished by each,

(2) explain the significance of certain detail provisions of these regulations where these are not clearly inferable from the text of the regulation itself,

(3) indicate means by which compliance may be shown,

(4) suggest or refer to forms in which data showing or implementing compliance may be presented.

## METHOD

The identification is accomplished by means of the Table of Contents hereafter which contains a list, by CAR Section Number and Subject, of these regulations. It is attempted to accomplish the remainder of the purposes described above by means of a brief INTRODUCTION presenting the background and history of the development of the category and to discuss certain general features of the nature of the regulations governing it and the procedure necessary to show compliance with these, followed by a detailed discussion of each of the Sections identified in the Table of Contents. Insofar as is practicable, each of these Sections is treated under each of the four elements, listed under PURPOSE above and, wherever possible, in that order.

## SCOPE

It should be noted (see CAR 04.01) that those Sections of the Civil Air Regulations which are identified by the Table of Contents are not all of the regulations with which compliance must be shown in order that an airplane be eligible for type certification in the Transport Category. They are rather only those Sections, governing the same subject matter, which differ from corresponding Sections in the Civil Air Regulations, applicable to all other airplanes, or those which are in addition to regulations applicable to all airplanes. It is believed that the text of the regulations themselves will make clear in which of the above two possible classes any one of them falls, but in all cases where this is not obvious, the status in respect of these two conditions is made clear in the text of this Manual.

## REMARKS

At this time no great amount of experience has been had in the administration of this set of requirements. For this reason, it is anticipated that this Manual will necessarily be subject to revision from time to time as experience with these requirements is gained. In view of this, and in order that possibly more useful means may be revealed which can be incorporated as revisions in the Manual, it is suggested that applicants for certification in the Transport Category look critically upon any means suggested herein to show compliance or any form in which to present test data. All criticism should be addressed to Flight Engineering and Factory Inspection Division, Civil Aeronautics Administration, Washington (25), D. C.

References to those parts of the Civil Air Regulations with which compliance also must be shown in order that an airplane may be certificated but which are not covered in this manual are given in Civil Aeronautics Manual 04 - "Airplane Airworthiness."

Additional information covering in detail the inspections and testing required for certification of an airplane in the Transport Category will be found in the Type Inspection Report form ACA 283-T. This form has been prepared by the Flight Engineering and Factory Inspection Division primarily for use of their personnel to serve as a guide and an outline of the scope of these inspections and tests as well as to serve as a standard form in which to report the results of these. Applicants desiring copies of this form for their own use may obtain them from any branch office of Flight Engineering and Factory Inspection Division or from the Washington office.

# INTRODUCTION

## HISTORY

The idea of categories of airplanes for design and other purposes is not new. Military airplanes have for years been classified in tactical categories such as, for example, fighter or pursuit, observation, attack, bombardment, training, etc., for each of which there exists a body of design requirements differing in detail from category to category. When, however, following the enactment of the Air Commerce Act of 1926, the problem of developing a set of design requirements for civil airplanes was faced, it was apparently felt necessary that these requirements be of such nature as to render them applicable to any airplane which might be presented for licensing.

Although the records are not entirely clear upon the point, there is certain inferential evidence, contained in the form which these requirements took when first published in 1928, that the purpose had been accomplished by taking the design requirements for the various military categories and expressing as many as possible of these as functions of certain of the fundamental design characteristics of the airplane. The airplane design characteristics selected for this purpose appear to have been weight and power loading and a great many of the structural design requirements remain today functions of these two parameters.

The successive revisions to these original requirements indicate, however, that this process was realized to be not altogether satisfactory. It has been found impossible to relate certain of the necessary design requirements to these parameters. Notable among such requirements were those governing the performance of the airplane: the take-off distance, the landing speed and the initial rate of climb. These had, instead, been made arbitrarily selected flat limitations applicable to all airplanes. Various not altogether satisfactory attempts were made at a comparatively early date to modify the inflexibility inherent in such requirements. The landing speed requirement, for example, was made successively a function of the presence or absence of brakes, the number of engines, the presence or absence of passengers, and finally, the weight of the airplane.

There is other evidence of dissatisfaction with a set of requirements applicable to all airplanes. For example, some time prior to 1934 Aeronautics Bulletin No. 7-E "Air Commerce Regulations Governing Scheduled Operation of Interstate Airline Services," had been prepared in which there occurred a great many design requirements, not found elsewhere in the regulations, applicable to what were identified as "airline aircraft." This represents, in fact, the first trace in the history of the regulations of what has since become the "Transport" category.

The trend in airplane design soon thereafter became most severely restricted by the landing speed requirement and resort was had to various expedients to relieve this restriction. Based upon dimensional reasoning now considered open to some question in respect of its fundamental assumptions, the landing speed was related to the weight of the airplane, permitting an increase with increasing weight. The conception of "provisional" weight was introduced into the regulations as a weight at which the airplane was permitted to take off, but not to land and at which compliance must be shown with all of the design requirements excepting only the landing speed. The granting of provisional weight, however, was limited to air carrier airplanes in scheduled operation. During early 1939 a tentative proposal to permit the granting of provisional weight to non air carrier airplanes was made but no action was ever taken. In August of 1939 another proposal for revision to the landing speed requirement was made, based upon maintaining an adequate spread between the stalling speed and an arbitrarily selected "approach" speed. This was also unfavorably received and no action was taken. Aircraft Airworthiness Section Report No. 8 dated August 1939, which dealt with the subject of flight load factors, recommended that operational classes or categories of airplanes be set up with constant load factors for each and proposed "Acrobatic", "General Purpose", "Land Transport", and "Ocean Transport" categories for this purpose. No action was taken upon this proposal.

Finally, in October of 1939 it was proposed by what is now Flight Engineering and Factory Inspection Division of the Civil Aeronautics Administration that there be established categories of airplanes based upon their intended use and that among these categories there be a "transport" category. There was also proposed a set of detail performance and flight characteristics requirements for the Transport Category which sought to avoid the inherent inflexibility of arbitrarily specified take-off distance and landing speed by substituting therefor the measurement of a take-off distance, intended to provide for the possibility of engine failure on multi-engine airplanes, and a landing distance; both to be representative of the airplane when operated within reasonable speeds, together with a set of operating requirements which related these dimensions to the dimensions of airports into or out of which the airplane would be permitted to operate in such a way as to provide a desirable level of safety.

This proposal was presented at a conference in Washington in October of 1939 attended by representatives of the entire industry and was well received. The entire proposal went through several successive drafts as the idea behind it developed, was again discussed at a similar conference in Kansas City in February of 1940, and was finally adopted by the Civil Aeronautics Authority May 28, 1940, as Amendment 56 to the Civil Air Regulations, to become effective July 1, 1940. Immediately after its adoption, however, objections began to be received from representatives of the manufacturing industry to various of its detail provisions, notably the take-off and landing distance requirements. The subject was re-opened for general discussion which continued during the greater part of the next two years, involved a number of investigations by the Civil Aeronautics Administration such as, for example, those covered by Flight Engineering Reports 1 and 2, several conferences, and finally a general revision of Amendment 56 adopted by the Civil Aeronautics Board February 6, 1942, to become effective July 1, 1942. This revision is reflected in the material discussed in this manual.

NATURE OF THE CATEGORY

The transport category is a category for the purposes of airworthiness and type certification. The regulations governing the category constitute an attempt to specify a minimum in the way of safety considered necessary for an airplane designed basically to be used for the transportation of passengers or goods.

The selection of the items of performance to be governed by regulations, as well as of the airplane configurations and speeds at which these items of performance are to be measured, have been based largely upon the practices of scheduled air carrier operation and have been aimed at reducing insofar as is considered practicable, the hazards which experience has indicated to exist in such operation. It has therefore been inevitable that the form of these regulations has been influenced by the types of airplanes upon which this experience has been based. Any radical departure in design is therefore likely to render some of the details of these requirements inappropriate. Such cases, however, cannot be anticipated and must therefore be dealt with as they arise.

As a result of a great deal of discussion during the development of the requirements, it has been decided that any airplane suitable for "transport" purposes should, in the interest of a minimum tolerable level of safety, be a multi-engine airplane. The regulations are therefore such that single engine airplanes are ineligible for certification in the category. This aspect of the regulations is reflected by various rates of climb required with one engine inoperative. It may also be noted that Section 40.2 requires that any new type airplane introduced into scheduled air carrier passenger operation must have been certificated in the Transport Category and that Section 61.712 imposes certain operating limitations upon such airplanes. These operating limitations are applicable to any part of any route flown by the airplane and take the form of specifying, in terms of the weight at which the airplane may be operated, a relation which must exist between certain items of performance measured as a part of the process of type certification and the dimensions of the route over which the airplane is operated.

It is, however, not intended that only airplanes for use in scheduled passenger operation be certificated in the category. For this reason the regulations include a set of minimum requirements for certification in the category. In the general case in which the applicant for certification anticipates the use of the airplane in scheduled passenger operation and thus becoming subject to the operating requirements contained in Section 61.712, it will be necessary, in order that these operating requirements be satisfactorily implemented, to consider all or the extreme values of weight, altitude, and such other variables as are involved in the application of these requirements. The performance information obtained in demonstrating compliance with the minimum requirements for certification in the category would limit the use of the airplane in scheduled passenger operation to sea level airports and to routes covering no terrain of greater altitude than 4,000 feet, and would require the imposition of the operating limitations of Section 61.712 at the maximum weights selected for that purpose. If the airplane be not used for scheduled passenger operation the minimum performance information required to be determined is considered to be necessary in order that the pilot may intelligently operate the airplane. It is for this reason, as well as for the reason that the information is necessary in order to comply with the operating requirements, that the Transport Category requirements specify that for each airplane an operating manual must be furnished which must contain certain of the performance information required for, and determined during, certification.

The fundamental distinction between the requirements of the Transport Category and those previously contained in the Civil Air Regulations and applicable to all airplanes, may perhaps be most aptly identified in terms of certain options, not at present otherwise necessary, which must be exercised by the applicant for certification in the Transport Category prior to or at the time of his application. These are identified and discussed in the following:

1. <u>The Selection of the Category in Which the Airplane is to be Certificated.</u>

   At present the alternatives to certification in the Transport Category are limited to a single set of requirements; namely, those in effect before the establishment of the Transport Category. As is indicated, however, by Section 04.01, an "acrobatic" and a "normal" category are now under consideration and will eventually be covered by appropriate requirements. It is also possible that in the future still other categories may be established. At present the practical significance involved in the selection of the category for certification is that unless certificated in the Transport Category, the airplane will not be eligible for use as a scheduled air carrier passenger airplane. Also, as has been indicated in the foregoing, single engine airplanes are in any event ineligible for certification in the Transport Category.

2. <u>The Selection of the Range of Weight and Altitude to be Covered by the Flight Testing Required for Certification.</u>

   This selection must be based primarily upon the extent to which the applicant for certification wishes the operation of the airplane to be limited following the original certification. If the applicant be not concerned with this point, he may elect to conduct only the flight test required to demonstrate compliance with the minimum performance requirements contained in Section 04.750-T together with those required to demonstrate compliance with the flight characteristics and other requirements. If the airplane is not to be used for scheduled air carrier passenger operation, or if it is practicable to limit the operation of the airplane by a scheduled air carrier to sea level airports containing runways of ample length and to terrain of altitude not in excess of 4,000 feet, this procedure appears to be indicated. It should be noted that this latter case could quite easily apply to a flying boat in scheduled operation. If, on the other hand, the applicant contemplates the use of his airplane in scheduled operation over land and wishes to provide for the greatest possible flexibility in the matter of compliance with the operation limitations contained in Section 61.712, considerably more performance measurement will necessarily be involved. It may be entirely practicable for example, for operation over routes involving appreciable differences in the altitude of airports along it, to take advantage of the improvement in performance which is possible by means of reducing the weight at which the airplane is operated. It may also be desirable to alter the various flap settings in order to improve the climbing performance at a given weight while not exceeding the limitations upon stalling speed at that weight. In cases such as these, it will, of course, be necessary to determine by flight testing and calculation, the effect of weight, altitude, and of flap setting, throughout the range of each for which it is desired to provide, upon the take-off, landing, and climbing performance and to include this information in the operation manual. This selection must obviously be left to the applicant since, even though he may find it difficult to anticipate the uses to which the airplane may subsequently be put, he is nevertheless in better position to forecast this than anyone else.

3. <u>The Selection of the Weight Range to be Covered by the Terms of the Certification.</u>

This selection is closely related to Item 2 in the foregoing and must be based upon essentially the same considerations. The simplest possible selection of weights is a single maximum weight to be used both for take-off and landing and as a basis for the imposition of the operating limitations. The next simplest choice would appear to be a maximum take-off weight and a maximum landing weight differing from take-off weight. This requires the installation of fuel dumping equipment of sufficient capacity to reduce the weight of the airplane from the maximum take-off weight to the maximum landing weight in not more than ten minutes. The operating limitations may then be based upon the assumption that these two weights exist throughout each flight. The most flexible possible arrangement in the matter of weights is provided by selecting a range of weights for take-off and a range for landing, and determining the performance as functions of these weights in order that, for the purpose of showing compliance with the operating limitations, any weight within these ranges may be selected to fit the requirements of a particular route. It is obvious that this selection must be left with the applicant.

4. <u>The Selection of the Range of Altitude to be Covered by the Terms of The Certification</u>

This is also closely related to Item 2 and is analogous in its nature to Item 3. The simplest possible selection is that indicated by the minimum performance requirements contained in Section 04.750-T; namely, sea level for the purposes of the determination of the take-off and landing distances and certain of the rates of climb and 5,000 feet for the purpose of determining the "en route" one engine inoperative rate of climb. The selection providing the greatest possible flexibility is to determine these items of performance over a range of altitude great enough to cover all anticipated routes over which the airplane may be operated.

5. <u>The Selection of the Wing Flap Positions Desired for Certification.</u>

Section 04.7512-T requires that the flap control indicate a "retracted," a "take-off," an "approach," and a "landing" position and it may be noted that it is required that various items of performance be determined at each of these flap positions. It is also required that the stalling speed with the flap in the "approach" position must not exceed 85 MPH, and that the stalling speed with the flap in the "landing" position must not exceed 80 MPH. Obviously, no plans for flight testing may be made until these positions are selected unless the applicant wishes to investigate systematically the effect of flap position upon each or several of the items of performance which must be determined at the nominal position to be selected. This selection may therefore be seen also to be related to Item 2 and possibly to Item 3.

6. <u>The Selection of the Critical Speed to be Used in the Determination of the Take-off Distance Required by Section 04.7532-T.</u>

This is discussed in the text associated with Section 04.7532-T.

The practical effect of these selections is that, by making them, the applicant defines, in terms of the elements involved therein, the area to be covered by the terms of the type certificate and thereby the limits of airplane weight and airport altitude within which the airplane may be operated by a scheduled air carrier in compliance with the requirements of CAR 61.712.

<u>PROCEDURE TO BE FOLLOWED BY APPLICANT</u>

The burden of showing or implementing compliance with the requirements for an airworthiness or a type certificate rests with the applicant for such certificate. The functions of Flight Engineering and Factory Inspection Division are to conduct such inspection and to witness and/or conduct such flight testing as is necessary to obtain the observed data and otherwise to demonstrate compliance with the regulations. CAM 04.0 outlines a set of minimum requirements for this process and a procedure to be followed by the applicant in order to satisfy the requirements for airworthiness or type certificates. In addition to the procedure contained therein, the following should also be done by the applicant for type certification in the Transport Category:

1. Prior to commencement of construction of any part of the airplane, notice of the intention to begin such construction and of the approximate date upon which it is to be undertaken should be given to the Chief, Flight Engineering and Factory Inspection Branch in the Region in which the type inspection is to be conducted, in order that he may arrange for the necessary inspection during the course of construction of the entire airplane.

2. In addition to that outlined in CAM 04.0320, which is ordinarily submitted to Aircraft Engineering Division, the following information should be submitted to the Chief, Flight Engineering and Factory Inspection Branch, prior to the final "freezing" of the design.



5-20767

(a) A three-view drawing of the airplane, fully dimensioned.

(b) A drawing, and sufficient description, of the flap control to indicate its status in respect of compliance with the requirements of CAR 04.434-T.

(c) A drawing of the trimming controls which will indicate the manner in which it is intended that they shall comply with the requirements of CAR 04.439-T.

(d) A drawing or diagram of the wheel brake system, together with an indication of the element(s) to be considered "lost" for the purpose of showing compliance with the requirements of CAR 04.445-T Also, a description of the method by means of which it is proposed to demonstrate, with this (these) "lost" element(s) inactive, that at least 50 percent of the normal deceleration during landing may be developed.

(e) A drawing of the pilot's enclosure showing azimuthal and vertical angles of vision with respect to the longitudinal axis of the airplane and the angular orientation of this axis in respect of the horizon for the normal ground attitude of the airplane; the attitude in a climb at the best rate of climb speed with METO power on all engines; and the attitude during a glide at 1.3 $V_{s_0}$ with the airplane in the landing configuration and the throttles closed.

(f) It is also strongly recommended that during this period a mock-up, which will include all of the crew stations and simulate all of the controls and instruments to be used by the crew as well as the windshield and any windows, be constructed by the manufacturer and made available to the representatives of the CAA for examination.

3. Prior to the commencement of any flying of the airplane, the applicant should notify the Chief, Flight Engineering and Factory Inspection Branch of the intention to do this and of the approximate date upon which such flights are to begin. If this be done, the representatives of the CAA may observe such of this preliminary flying as may be deemed expedient by the Chief, Flight Engineering and Factory Inspection Branch, in order that such observed data as may appear to be adequate for the showing of compliance with the requirements may be obtained, thus reducing the extent of official flight testing and also the amount of flying which might otherwise be necessary in order that the applicant submit a complete flight test report prior to the submission of the airplane for official flight tests.

4. Prior to the presentation of the airplane for the official type inspection, the applicant should submit to the Chief, Flight Engineering and Factory Inspection Branch, a proposed program which will indicate at least the following:

(a) The area defined by the several selections described under NATURE OF TRANSPORT CATEGORY above to be covered by the terms of the type certification.

(b) A flight test program which will clearly indicate all of the tests it is proposed to conduct; the order in which they are to be conducted; the purpose of each such test; and for each, the airplane weight, c.g. position, flap setting, power to be drawn, and, where appropriate, the altitude, the trim speed(s) and the speed(s) or speed range to be investigated. It is suggested that this program will be most useful if, for each section of the CAR requiring flight tests, it indicates the tests proposed and also indicates, in order, each flight to be made and, for each, in order, the tests to be conducted.

(c) A description of the method(s) which the applicant proposes to use in order to reduce the observed data to standard conditions.

(d) A statement of any intention on the part of the applicant to resort to calculation in lieu of or for the purpose of generalizing test data, together with a description of the data upon which these calculations are to be based and the methods to be used therein.

Since it will require time for the Administrator's staff to determine the adequacy of this entire program, it is strongly recommended that it be submitted as early as practicable. Otherwise, the commencement of the testing may be delayed.

5. During the type inspection the applicant must, of course, make available the airplane for that purpose as well as all of the personnel and equipment necessary to obtain the required data. The CAA possesses certain indicating instruments which may be used for this purpose such as, for example, a trailing bomb, sensitive altimeters, stop watches, carbon monoxide indicators, etc., as well as photographic equipment for measuring take-off and landing flight paths. It is therefore recommended that the matter of instrumentation be discussed with the Chief, Flight Engineering and Factory Inspection Branch in the applicant's region prior to any decision as to the detailed flight test program.

6. Upon the completion of the type inspection, the applicant should prepare the information necessary to show compliance with the requirements and the airplane operating manual required by CAR 04.755 and submit them to the Flight Engineering and Factory Inspection Branch as promptly as possible. Promptness is necessary in order that these data may be examined and a decision taken concerning the eligibility of the airplane for, and the appropriate terms of, type certification made within the 60-day period beyond which the airworthiness certificate is valid indefinitely unless revoked. Otherwise it may be necessary to suspend the certificate at the end of the 60 days until this process can be completed. No scheduled air carrier operation of the airplane will be authorized until the process of type certification has been completed.



5-20767

## 04.401 - Airplane Categories

It should be noted that the regulations now contain sections identified by the suffix system here described, for the Transport Category only.

## 04.434-T - Flap Controls

The ability of the airplane to comply with the maximum stalling speeds of CAR 04.7530-T and the minimum rates of climb required by CAR 04.7531-T may be seen to depend critically upon specific flap positions. The operating rules for Transport Category airplanes contained in CAR 61.712 specify a maximum take-off weight such that with the "take-off" flap setting it is barely possible in the event of engine failure either to stop within the length of the runway or proceed on the remaining engine(s) and attain a height of 50 feet at the end of the runway. A lesser flap setting would improve the ability of the airplane to climb and therefore to reach the 50 ft. altitude, but would worsen its ability to stop within the field. A greater setting would improve the ability to stop but worsen the ability to climb to 50 feet. Similarly, the operating rules in effect specify a maximum landing weight such that with an "approach" and a "landing" flap setting it is possible safely to execute an approach and landing, or, if necessary, to interrupt the landing process and "go around" for another attempt. Lesser flap settings would improve the ability of the airplane to "go around" but would require more distance to land and conversely for greater flap settings. Also, at some point during the complete process it is necessary to change from the "approach" to the "landing" flap setting, or from one or the other of these to "retracted" setting; i.e., it may be necessary that the crew select and obtain a precise flap setting under operating conditions such that the crew can devote a minimum of attention to the process or during an emergency, and, further, the safety of the operation demands that it be done surely.

It may also be noted that the maximum stalling speeds are specified as true indicated air speeds and are, therefore, independent of altitude, while, at a given flap setting and weight, the rate of climb available ordinarily decreases with altitude. This suggests the possibility, where operation of the airplane at airports having various altitudes is contemplated, that optimum conditions in respect of carrying the maximum weight permitted by the stalling speed and rates of climb requirements would be obtained if the flap positions corresponding with the required flap control settings were made variable with altitude (i.e., the flap extension corresponding with a given control setting should decrease with increasing altitude of the field.)

The purpose of this requirement is to specify a flap control which will permit the accomplishment of the use of the flap described above with the minimum of attention on the part of the pilot and co-pilot. While it is not required that it be possible to stop the flap at any point between the positions corresponding with any adjacent pair of the required control settings, which would provide more flexibility in the use of the flap than otherwise, nevertheless this is considered desirable unless the provisions necessary to accomplish this impair the reliability of the control mechanism to produce the flap positions corresponding with the required settings. There appears also to be no objection to providing for extension of the flaps beyond the position corresponding with the "landing" control setting provided the control clearly indicates it to be beyond this setting and so provides warning to the crew that the minimum rate of climb is not available. It should be also noted that CAR 04.7533-T permits the use of such flap position in the determination of the landing distance.

The only flap control mechanism designed to comply with this requirement with which we have had experience was an electrical one; the control being in effect a multiple position switch. It appears necessary also to provide a flap position indicator with any control mechanism such as is required by this section of the regulations, in order that the crew may have means to verify that the mechanism is operating satisfactorily.

Finally, it should be noted that the degree of complication of the flap control is largely open to selection by the applicant for type certification. (See 04.7512-T below.)

04.439-T - Trim Controls

The first sentence of this section requires trim controls so designed that, in the event of failure of the corresponding primary control, the trim control will still continue to perform its normal function. This is considered a reasonable safety precaution because, in the event of primary control failure but with a trim control capable of continued operation, it may be possible, by means of the trim and powerplant controls, to land safely. Whereas, if the trim control is also inoperative a safe landing would be very difficult to make and could be catastrophic particularly in the case of failure of the elevator control.

The second sentence in its effect requires standardization of the trimming controls for all transport category airplanes. This is required in an effort to avoid the possibility of improper operation, particularly during emergencies, or the shifting of crews from one type airplane to another, and to relieve the load upon the attention of the flight crew which the operation of an airplane of that type requires, by providing trim controls uniform in their operation. This is considered warranted in view of the present much greater dependence which is placed upon the trimming devices than when they were first generally introduced into airplane design.

The motion of the airplane to which the text of the section refers is a rotary motion; i.e., the motion involved in longitudinal or "elevator tab" trimming is a rotation about the lateral axis of the airplane and the plane of this motion is the plane of symmetry or a plane parallel to it. The sense of the motions is, therefore, a direction of rotation which the regulation requires to be the same as that of the airplane. Practically, the section requires that each trim control handle be either a wheel or a crank completely exposed and that it be located and operated as follows:

(a) The longitudinal or "elevator" trim control must be so located as to



5-20767

rotate about a lateral axis and must rotate clockwise when viewed from the left to produce "nose up" trim, or to reduce the speed or to reduce the primary control force required to maintain a speed lower than the trimmed speed.

(b) The lateral or "aileron" trim control must be so located as to rotate about a longitudinal or "fore and aft" axis and must rotate clockwise when viewed from aft to lower the right or starboard wing.

(c) The directional or "rudder" trim control must be so located as to rotate about a normal or "vertical" axis and must rotate clockwise when viewed from above to change heading to the right.

It should be noted that Sections 04.435 and 04.4350 also apply to the Transport Category and that, therefore, the installation of an elevator tab position indicator is required. Position indicators are recommended for all trimming tabs or for any other element actuated by the trimming device.

<u>04.445-T - Brakes</u>

This requirement is based upon the fact that compliance with the operating rules of Section 61.712 will require great dependence upon the presence and proper functioning of brakes unless the runways involved are unusually long. Its purpose is believed clearly indicated by the text of the regulation itself.

The nature and extent of the "test or other data" required to show compliance with this requirement will necessarily depend upon a great many things such as, for example, the general arrangement of the landing gear, the design of the brake system, the extent to which the capacity of the brakes is used in establishing the landing distance required by CAR 04.7533-T, the amount of available performance data for the brakes, etc. The simplest possible procedure would appear to be to determine the average deceleration during a landing ground roll using no brakes and then to establish the landing distance required by CAR 04.7533-T by using the brakes to the extent necessary to double the mean deceleration so established. It appears likely, however, that this procedure would result in excessive landing distance and might seriously limit the use of the airplane in scheduled operation.

If it is desired by the applicant to make the maximum possible use of the brakes in establishing the landing distance, and if also the contribution of the brakes to the total deceleration is relatively large, it will be necessary so to design the brake system as to permit the application of slightly less than half the braking deceleration so developed, under the conditions specified in this section. The safest arrangement which would permit this, appears to be the installation of a dual system; i.e., dual wheel elements (drums or disc units) transmitting elements, power sources, master cylinders, etc., connected to a single pedal on each rudder pedal, such that the failure of any single one of these would leave half the total braking capacity symmetrically disposed about the plane of symmetry of the airplane. With such a system it should be possible to show compliance with this section by means of calculation based upon the test data necessary to establish the landing distance plus those obtained as a part of the certification process for the brake (See CAR 15.104). Such a braking system is recommended.

If the system be so designed that under the conditions here specified appreciably less than half the total braking capacity remains or if the remaining capacity be asymmetrically disposed, it will almost certainly require tests to determine that half the mean deceleration may in fact be developed and/or that the airplane may be safely controlled directionally while doing so. In the case of a conventional landing gear it appears most unlikely that any appreciable braking effort might be safely applied on one side only of the airplane.

The decision, therefore, rests with the applicant. It is recommended however, that the question be considered well in advance of presenting the airplane and that, once the decision be taken, it be communicated to the Civil Aeronautics Administration, together with drawings of the installation, a proposal concerning the element or power source to be considered inoperative, and an outline of the method (tests, calculations, etc.), by means of which it is proposed to show compliance.

## 04.70 - Performance Requirements

The significance of this section in respect of the Transport Category is merely that it states which of the succeeding sections are and which are not applicable to airplanes certificated in the category.

## 04.707-T - Flutter and Vibration

The requirements of this section are considered to be clearly stated by its text. It is not anticipated that any special flight testing will be necessary to show compliance beyond the usual dive test required of all airplanes unless difficulty be encountered during this or any other necessary testing.

## 04.75-T - Performance Requirements for Transport Category Airplanes

## 04.750-T - Minimum Requirements for Certification

The primary significance of this section is that it provides means by which an airplane may be certificated in the Transport Category even though it may not subsequently be placed in scheduled passenger carrying operation, and, as a result of such, be subjected to the operating rules of CAR 61.712. Items (a), (b), (c), and (d), simply define a minimum number of weights and altitudes at which the performance must be determined, (see INTRODUCTION, NATURE OF THE CATEGORY, and Item 2 thereunder). Item (e) means simply that the airplane must, at these weights and altitudes, comply with all the applicable requirements, (see CAR 04.01, 04.70, and 04.75-T).

The amendment to the certificate to which the last paragraph of this section refers will in practice be the revision of the Airplane Operating Manual required by CAR 04.755-T to include the performance information corresponding with other weights or altitudes.

## 04.751-T - Definitions

### 04.7511-T - Stalling Speeds

The text of this Section is believed to be quite clear. The speeds are so formally defined because they become the basis for the specification in the following Sections of other speeds as multiples of these and required rated of climb as multiples of their squares. These stalling speeds are defined as "throttles closed" because greater consistency may be expected among the results of successive attempts to measure them than from attempts when appreciable power is drawn and they are, therefore, more useful for their basic purpose. Since the effect of power is ordinarily to decrease the stalling speed, they are also conservative for these purposes.

All stalling speeds required to be investigated are measured by means of flight tests by first calibrating the airplane air speed indicator by flying over a measured course at various indicator readings or using a trailing bomb, then stalling the airplane, following the procedure of CAR 04.7543-T. The stalling speed is the lowest indicator reading observed during steady controlled flight following this process, corrected by the results of the calibration.

### 04.7512-T - Flap Position

The flap positions corresponding with the flap control settings required by CAR 04.434-T are open to selection by the applicant. The only regulatory restrictions upon this selection are that, once made, the weight at which the airplane may be operated must not exceed that at which the maximum stalling speeds (CAR 04.7530-T) and the minimum rates of climb (CAR 04.7531-T) are equalled, or, in scheduled operation, that at which the take-off (CAR 61.7122) and landing (CAR 61.7123) limitations are equalled.

The simplest possible choice would appear to be the retracted flap position for "take-off" and "approach" and the fully extended position for "landing". This conforms to most of the past practice in the use of flaps and requires a comparatively simple control mechanism. If, however, the airplane has been so designed that the maximum take-off and landing weights are limited by the required rates of climb at sea level, these weights will be reduced more rapidly with increasing altitude than would otherwise be required since the effect of a given small change in flap position upon the maximum weight permitted by the climb requirements is generally appreciably greater than its effect upon the maximum weight determined by the stalling speed requirements. Also, it is very possible that, for an airplane so designed, the distance required to accelerate during take-off to the minimum required speed and stop, may, at a given weight (less than the maximum), greatly exceed the distance required to reach a height of 50 feet. (See CAR 04.75320-T) and 04.75321-T.) Since the scheduled operation of the airplane will be limited to weights such that the greater of these two distances does not exceed the length of the take-off runway, it may be advantageous to use a "take-off" flap position such as to make these two distances more nearly equal. This could be done by using some flap extension since with increasing extension the speed to which the airplane must be accelerated may be reduced (See CAR 04.75320-T) and the drag during the deceleration run will probably be increased both of which will, at a given weight, reduce the accelerate-stop distance. Flap extension would also decrease the stalling speed, and, therefore, the required rate of climb, as well as decrease the available rate of climb, but the net result would normally be an increase in the distance required to attain 50 feet of height. The optimum "Take-off" flap position for a given weight; i.e., the position such as to require a minimum runway length, would be a position such as to make these two distances equal.

The most complicated selection to which there appears to be point would be one such as to permit the airplane to carry the maximum possible weight permitted by the operating limitations of CAR 61.712 at any altitude for any possible runway length. Such flexibility in operation would, however, require secondary flap control systems of such complexity as to present a substantial design problem.

The selection of flap positions will also influence the nature and extent of the flight testing required for type certification. If, for example, a single flap position be used for each of the required control settings, it is only necessary to measure the stalling speeds at one weight and rates of climb at such weights and altitudes as may be necessary to cover the range of each for which the applicant wishes the airplane certificated. If, on the other hand, a number of flap positions are to be used for one or all of the required control settings, dependent upon altitude, runway length or other parameter, it will be necessary to measure stalling speed and climbing and other performance at each such position or at a sufficient number of these to permit the determination of the performance at all of them by interpolation or other suitable means.

04.7513-T - Maximum One-Engine-Inoperative Operating Altitude

This section in its effect defines a minimum rate of climb which is acceptable as evidence of the ability of the airplane to maintain altitude in spite of the failure of an engine during cruising flight. The altitude, in standard air, at which this rate of climb exists under the conditions here specified becomes the basis for the operating rule specified in CAR 61.7125. The required rate of climb has been related to the stalling speed because the ability of the airplane to reach an intended point for landing is approximately proportional to the rate of climb; the failure to do so may result in a forced landing during which any damage done to the airplane or its contents is assumed to be related to the kinetic energy which must be absorbed; and this energy is proportional to $V_{s_0}^2$.

As the text of this section indicates, CAR 04.723 also applies to the Transport Category and the data obtained from the testing required by that section are adequate to establish the maximum one-engine-inoperative operating altitude and its variation with airplane weight. The process by means of which this may be accomplished is described in Flight Engineering Report No. 9. The testing required at each altitude and weight is outlined in Section IV,G, of the Type Inspection Report Form (ACA 283). The nature of this testing and an acceptable method by means of which to reduce the observed data to standard conditions is described in Flight Engineering Report No. 3.

The number of weights and altitudes at which tests must be conducted depends upon the range of weight and altitude to be covered, the altitude characteristics of the powerplant, the consistency of the results of the testing actually conducted, etc. The number must, however, be great enough to establish at least the following:

1. The critical altitude(s) of the engines for METO power.

2. The apparent aerodynamic characteristics of the airplane; i.e., airplane efficiency factor "e" and parasite area "f" or their equivalent.

3. The rate of change with altitude of best rate of climb between all critical points in the altitude history of METO power.

The absolutely minimum amount of testing which appears likely to do this is to conduct at one intermediate weight a five speed sawtooth climb at not less than two altitudes in any full throttle range between adjacent pair of critical points in the altitude characteristics of the powerplant, independently to determine all critical altitudes, and thus to establish rate of climb versus altitude for that weight. Experience has indicated that it is necessary to carry out the climb at each speed during these sawtooth climbs for at least five minutes in order to obtain dependable results. The effect of weight may then be calculated, by the method of Flight Engineering Report No. 10 or its equivalent, at each of the critical points to establish the altitude history of climb at other weights.

It is recommended that compliance with this requirement be shown with the cowl flap position required to meet the powerplant cooling requirements (CAR 04.640 and Form ACA 283, Section III,E). The applicant may, however, show compliance with the cowl flap position required for cooling in standard air. This will of course require additional cooling tests to establish this latter cowl flap position.

<u>04.752-T - Weights</u>

The regulatory limitations upon the weight at which Transport Category airplanes may be certificated are conveniently summarized beginning on Page 2 of Flight Engineering Report No. 9, which indicates all the factors which should be considered by the applicant prior to selecting the design weights. It may be noted that this section requires the design landing weight to be not less than 87% of the design take-off weight and that CAR 04.7520-T requires the installation of dump valves if the take-off weight exceeds the landing weight. Although not explicitly stated, the regulations as well as practical considerations, indicate the necessity, in all cases where the take-off weight exceeds the landing weight, of providing fuel capacity for a weight of fuel in excess of the maximum spread between any take-off and landing weight to be authorized for any scheduled flight. Where it is desired to use a take-off weight that exceeds the maximum allowable landing weight by more than 15%, this may be accomplished by designing the airplane for landing loads corresponding with a weight not less than 87% of the take-off weight, and by providing fuel dumping facilities adequate to reduce the weight from the take-off to the landing weight in ten minutes.

04.7520-T - Fuel Dumping Provisions

The basic purpose of this requirement, as the text indicates, is to provide for landing at a weight not in excess of the maximum landing weight and it assumes, if the weight of the airplane can, by the dumping of fuel, be reduced from the maximum take-off to the maximum landing weight in not more than ten minutes, that adequate provision has been made against the probability of having to make a landing at a weight in excess of the maximum permissible landing weight. It is not the purpose of the requirement to provide a means by which the climbing performance of the airplane may be improved in an emergency by reducing the weight of the airplane. This latter, in order to be effective, would require a much more rapid dumping than is here required or it appears practicable to provide.

The purpose of the testing is to demonstrate that the required amount of fuel may be dumped in the required time during any flight condition in which dumping must be done and that the dumping process is relatively safe when undertaken in any of the flight conditions here enumerated. The required testing is outlined in Section VI,E,4, of the Type Inspection Report Form (ACA 283).

It is required that a suitable colored non-inflammable fluid be dumped in order to explore the possible hazard involved in dumping in advance of actually dumping fuel as well as to establish the flow pattern should a first attempt disclose that some part of the discharge contacts some part of the airplane. For this reason the fluid should, if possible, have approximately the same specific gravity as fuel; (i.e., about 0.72) and the coloring material should be such that it will readily deposit on the external surface of the airplane. Non-inflammable fluids of such specific gravity are rare and water is ordinarily used.

04.753-T - Required Performance and Performance Determination

The items of performance which are governed by minima or otherwise required to be determined hereunder, all involve one or more of the following basic regimes:

1. The airplane being accelerated along the ground from rest to some specified airspeed.

2. The airplane climbing or gliding steadily.

3. The airplane being decelerated along the ground from some specified airspeed, or a contact speed during landing to rest.

The fundamental nature of these operating regimes is indicated in Flight Engineering Reports 7, 3, and 1, respectively, which also contain or discuss acceptable methods by means of which to correct the observed data to standard conditions. Flight Engineering Reports 9 and 10 indicate methods by means of which the required performance may be calculated for various weights and altitudes once it is established for one weight and certain altitudes and the former of these two reports sheds considerable light upon the nature and extent of the testing required to establish the required performance.

The take-off flight path, specified hereunder, ignores the transition which, in any real take-off, must take place between linear acceleration along the runway to steady climbing flight because no significant error is ordinarily introduced by doing so. The landing flight path does not, however, ignore the corresponding transition from steady gliding flight to deceleration along the ground. The nature of these transitions is discussed in an article, "An Approximate Method to Predict the Transition or 'Flare' Flight Path in the Take-Off or Landing of an Airplane" in the November 1941 issue of the Journal of the Aeronautical Sciences.

The only information available to the CAA concerning the accuracy of the results of direct tests undertaken to determine any one of these three basic items of performance is the consistency of the results of successive attempts to measure any one of them. The results of such tests for the distance required to accelerate along the ground to some selected speed indicate very great consistency. Figure No. 19 of Flight Engineering Report No. 7 shows, for example, that when the results of five separate measurements are plotted as velocity against distance, the points for all practical purposes, define a single curve. This is believed to indicate comparatively great accuracy in establishing such a distance. The case of rate of climb is not so fortunate. The information available is by no means conclusive, but it does indicate that rate of climb cannot be established by direct testing within such close limits of precision, and that rather extensive flight test data are likely to be necessary in order to establish representative values of this item of performance. The case of deceleration along the ground has also proven to be troublesome. There are really two cases to be considered. The first of these is the deceleration following contact during a landing. Flight Engineering Report No. 1 contains the results of 38 landings made with one airplane, and the discussion beginning on Page 39 of that report, plus the tabulation of corrected results on Page 67 of the report, will indicate the order of consistency of the effective constant deceleration involved. The other case is deceleration following the abrupt stopping of the engines simulating the case of engine failure during the take-off. Flight Engineering Report No. 7 contains the results of several attempts to measure this distance from various speeds. These results appear in Figure No. 24 of that report. There are a number of reasons for the dispersion of these results, the more important of which appear to be the condition of the brakes and the consistency of the pilot technique.

The variation of the probable accuracy of the measurement of these three basic items of performance produce a corresponding variation in the amount of direct testing which would be required to establish them. In the case of the distance required to accelerate to a speed, for example, it is believed the results of three separate attempts would probably be definitive. The amount of testing required to establish the rate of climb at one weight throughout the range of altitude has already been discussed under Section 04.7513-T above. It is difficult to be very specific concerning the amount of testing required to establish the distance required to decelerate from a given speed. It is considered unlikely, however, that a representative value could be established by means of less than five consecutive attempts to measure the distance required to decelerate from a given speed.

04.7530-T - Stalling Speed Requirements

The limitations which are imposed by the requirements of this section upon the stalling speeds have been dictated primarily by the effect of the speeds at which it is necessary that the airplane be operated during an approach and landing under adverse weather conditions, upon the safety of that operation. All of the airplanes which had been used in civil operation had, at the time these regulations were written, been designed to comply with a maximum landing speed requirement which had in no case exceeded 70 MPH where passengers were to be carried in the airplane. Even though there are contained in the entire set of Transport Category requirements other but less direct limitations upon these stalling speeds, it was considered unwise to abandon any direct limitation because the alternative limitations are not absolute and it is, therefore, possible by the installation of a sufficient amount of power in an airplane and by the provision of airports having runways long enough, to design an airplane having stalling speeds far in excess of those with which we have been familiar.

The purpose of Item (a) of this Section is to prevent the necessity of making contact at very high speeds during landing. The purpose of Item (b) is basically to provide a margin of speed between the stalling speed and the maximum which it is believed may be safely used during the instrument let-down and approach procedure. This margin is such as to provide for an acceleration of 2g, corresponding with a 60° banked turn at 120 MPH without stalling. It should be noted that these are true indicated airspeeds as defined in Section 04.7511-T.

These stalling speeds must be established by flight tests at at least one airplane weight, ordinarily the maximum landing weight.

04.7531-T - Climb Requirements

This section specifies a minimum rate of climb for each of three airplanes configurations representative of three different operating conditions certain to be encountered in the use of the airplane. These rates have been specified with two basic purposes in mind. The first of these is that they are believed to be a minimum which will guarantee the ability of the airplane to perform any necessary maneuver safely. The other is that they penalize the extreme use of wing flaps for the purpose either of complying with the stalling speed requirements or of establishing the minimum possible take-off distance at the greatest possible weight. The use of a comparatively great amount of flap during the landing increases the difficulty in executing the landing: first, because it increases the rate of descent at a given approach speed, and, second, because it results in a trim with the nose of the airplane lower than would be required without or with lesser flap such that the rotation of the airplane about its lateral axis, which is involved in the final stage of a landing, must take place over a greater angular range. These rates of climb are also related to stalling speed for essentially the same reason as has been stated in the discussion of Section 04.7513-T.

The nature and extent of flight testing required to establish these rates of climb depends upon the range of weight and altitude for which it is desired the airplane be certificated. If a moderate range of altitude (sea level to



S-20767

5 or 6,000 feet) is involved, and if, also, the testing specified under Section 04.7513-T has been conducted, a five speed saw-tooth climb at a single weight and altitude for each of these three configurations will probably be adequate to establish values of airplane efficiency factor "e" and airplane parasite area "f." It should be noted, however, that the effect of the slipstream upon the apparent aerodynamic characteristics of the airplane will vary with altitude and if there is any great variation in horsepower available over the range of altitude involved it may be necessary to investigate more than one altitude.

(a) Flaps in Landing Position
The airplane configuration here specified is that ordinarily used in the final stages of an approach for landing and the purpose of the rate of climb here specified is to insure that the airplane be able to "go around" for another attempt at landing in the event conditions beyond the control of the pilot makes this necessary.

(b) Flaps in Approach Position
This airplane configuration is intended to represent conditions which would probably occur during an approach for landing with one engine inoperative and the rate of climb is intended to insure that the airplane be able to "go around" in the event this becomes necessary.

(c) Flaps in Take-Off Position
This airplane configuration is intended to be representative of the conditions which might be expected to occur in the event of engine failure at about the time the airplane leaves the ground during take-off, and the rate of climb specified is believed to be a reasonable minimum which will insure the ability of the airplane to continue the take-off under such circumstances. The landing gear is specified as retracted on the assumption that the retraction will be started at practically the instant of leaving the ground. The inoperative propeller control is specified in a position which would allow the engine to develop at least 50% of maximum except take-off engine speed upon the application of power, upon the assumption that a pilot would almost automatically pull the propeller pitch control to a comparatively low RPM setting but not so low that, in the event the engine recovered, practically no thrust would be available due to the high pitch setting of the propeller.

The determination of the allowable propeller control setting for the purposes of compliance with this requirement will ordinarily require that the airplane be flown at the speed involved in order to determine whether the constant speed control will govern at 50% of maximum except take-off RPM while drawing power at the limiting manifold pressure, the maximum cruising BMEP recommended by the engine manufacturer, or full throttle whichever shall occur first as the throttle is opened. If so, this propeller control position must be noted and the tests to establish the rate of climb conducted with the control of the inoperative engine set to this same position. If the constant speed control will not govern while drawing power as described above;

i.e., if, with the control in the "minimum RPM" position 50% of METO RPM be exceeded, the climb testing will be conducted with the control in that position.

If the design or operation of the propeller control mechanism is such as to render the above procedure inapplicable, consideration will be given to any alternative which conforms with the basic purpose of the requirement, this purpose being to permit such betterment of the rate of climb as might result from a single and practically instantaneous operation of some single propeller control which would not, however, permit the pitch of the propeller to exceed that established above drawing power, i.e., that pitch corresponding with 50% METO RPM under the specified throttle setting.

## 04.7532-T - Take-Off Determination

The purpose of this requirement is to establish the dimensions of a take-off flight path such that if the take-off runway have a length equal to the greater of two possible dimensions of that flight path, an engine failure may be suffered by the airplane at any point within the length of that runway and the airplane be able either to stop within the length of the runway or to continue and clear all obstructions to flight until a safe landing may be made. Such a flight path necessarily involves consideration of the level of skill of the pilot who happens to be flying the airplane at such a time, and it has been attempted in the specification of the conditions under which this flight path is to be established, to provide for a reasonable level of skill by specifying certain minimum speeds which must be attained, as well as a sequence and timing in which it is assumed various adjustments may be made to the airplane, each of which would have measurable effect upon the resulting dimensions. These particulars are discussed in the immediately succeeding sections.

## 04.75320-T - Speeds

This Section, as its text indicates, contemplates a speed at which the engine may be assumed to fail which may be lower than a speed at which flight is possible. Since the operating requirements of CAR 61.712 limit the take-off operation of the airplane to a weight such that in the event of engine failure at the critical engine failure speed the airplane may either be brought to rest within the length of the field or continue the take-off and attain a height of 50 feet at the edge of the field, it follows that for any airplane at a particular weight there is an optimum value of this critical engine failure speed which will produce the minimum required runway length and further, that this optimum condition obtains when the two alternative distances are equal. In the case of an airplane having a comparatively high wing loading but low power loading and particularly in the case of airplanes with four or more engines, this optimum may be appreciably below a speed at which flight is possible. If such a speed is to be used for the purposes of establishing the dimensions of the flight path, it is obviously necessary that it be possible to continue the take-off acceleration after the failure of an engine until a minimum safe flying speed has been attained and it must be demonstrated by test that it is possible safely to do this. It appears open to some question whether any airplane equipped with a conventional landing gear arrangement can do this although it does appear possible that an airplane equipped with a tricycle landing gear might do so.

The second speed specified by this Section is a minimum speed at which it is considered safe to attempt to complete the take-off with one engine inoperative. The limitation upon this speed based upon stalling speed involves the power off stalling speed and the 20% and 15% margins are arbitrarily specified as a reasonable minimum to insure against inadvertent stalling of the airplane. The difference between the two margins based upon the number of engines installed in the airplane is due to the fact that the application of power ordinarily appreciably reduced the stalling speed. In the case of the two engine airplane, at least half of this reduction is eliminated by the failure of an engine. In the case of a four engine airplane, certainly less than half and probably more nearly one-quarter only of the difference is eliminated by the failure of an engine. The difference in the required factors therefore provides approximately the same margin over the actual stalling speed under the power conditions which obtain after the loss of an engine no matter what the number of engines (in excess of one) may be.

This minimum take-off climb speed is also required to be at least 10% in excess of the minimum speed at which the airplane can be safely controlled when the critical engine is suddenly made inoperative. Flight tests are required to determine this latter speed and it is suggested that the most direct testing technique would consist in making the critical engine inoperative at a speed above the probable minimum and then slowly reducing the airplane speed until a minimum is reached. This minimum should then be checked by flying steadily at the speed so determined with all engines operating, closing the throttle on the critical engine and verifying that control can be maintained. For the purposes of compliance with this requirement, the rudder pedal force required, without adjustment of the trim, to hold the airplane steadily upon a heading with zero yaw shall not exceed 180 pounds. This condition of trim will ordinarily involve two or three degrees of roll, the wing on the side of the operating engines being down. It should also be noted that during the test required to verify the minimum controllability speed appreciably greater roll than this may be required momentarily in order to regain control and this is acceptable so long as control can be established with reasonable promptness at the same speed and without loss of altitude. Finally it should be noted that 04.7540-T requires that this speed be not more than 1.20 $V_{s1}$.

The selection by the applicant of the two speeds specified by this Section will influence the nature of the testing required to establishing the take-off flight path specified in the succeeding Section. If the critical engine failure speed, $V_1$, is equal to or in excess of the minimum take-off climb speed, $V_2$, the segment of the take-off flight path involving acceleration along the ground may be determined separately from those succeeding segments which involve steady climbing flight. If, however, $V_1$ is less than $V_2$, the testing must involve a take-off acceleration during which the critical engine is made inoperative at the speed $V_1$, but the acceleration continued at least until the speed, $V_2$, is attained and the resulting flight path recorded photographically.

In either event the critical speed thus determined should be included in the Operating Manual (see Section 04.755-T).

04.75321-T - Take-Off Path

The take-off path specified by this Section involves the determination of the distances traversed by the airplane for two alternative sequences of events. The first of these is that the airplane be accelerated to the critical engine failure speed, at which speed all engines are made inoperative and the airplane decelerated to rest. The second sequence of events is that the airplane be again accelerated to the same speed but that at that speed, the critical engine only be made inoperative and the take-off continued under certain specified conditions. The distance required to accelerate to the speed, $V_1$, is thus common to both sequences.

The first of these assumed sequences of events will be called hereafter the "accelerate-stop" distance. It is obvious that when the throttles are suddenly closed, a finite time will elapse before the propellers and the rotating parts of the engine are decelerated from the take-off RPM at which they are, prior to closing the throttle, being driven; to an idling RPM. During this period the propellers continue to exert thrust until a certain zero thrust RPM is reached as a result of the deceleration. For this reason the speed of the airplane continues to increase beyond that which exists at the moment the throttles are closed before it begins to decrease again. The period of time covered by this deceleration of the engine RPM is also a very critical period for the application of brakes since there usually results a change in trim of the airplane and certain adjustments in the position of the controls must be made. For both of these reasons it appears necessary, in order to establish a representative dimension for the distance that would be required in the event of an actual failure of an engine during take-off and the election of the pilot to stay on the ground, to conduct tests involving a continuous run starting from rest and ending at rest rather than to determine separately the distances required to accelerate to the selected speed and the distance required to decelerate from this speed when this latter maneuver is performed as a part of a landing. This process ordinarily requires a comparatively long runway and in some cases it has been found impossible to attain the required speed and stop within the available length of a runway. If this cannot be avoided, it then becomes necessary to determine the total distance involved in accelerating to various lower speeds such as to permit extrapolation of the results to the required speed. In determining this distance, the wing flap shall be in the take-off position at least until the engines have been made inoperative but they may thereafter be extended to aid the deceleration if it is demonstrated by the applicant that this may be done with reasonable ease and with safety.

The second sequence of events identified above produces what will hereafter be called the take-off flight path. This is made up of the following segments:

1. Acceleration along the ground. This has been discussed in the foregoing.

2. Steady climbing flight with critical engine inoperative. The inoperative propeller idling with its pitch control in the take-off position and the landing gear extended for the length of time required to retract the landing gear.

3. Steady climbing flight with the landing gear retracted and the inoperative



5-20767

propeller pitch control in the position permitted by CAR 04.7531-T(c) for the length of time required to attain a height of 50 feet above the take-off surface and thereafter, for the length of time required to feather the propeller.

4. Steady climbing flight with the inoperative propeller feathered for the length of time which may remain of the time limit upon the use of take-off power. Cases have been encountered in which propeller feathering is incomplete at the end of one minute from the start of the take-off and in such cases the flight path has been based upon the assumption that take-off power would continue to be drawn during an emergency such as would exist following the failure of an engine during the take-off, until the propeller is in fact feathered.

5. Steady climbing flight with the inoperative propeller feathered drawing maximum except take-off power upon the operating engine(s) indefinitely thereafter.

It may be noted that Items (e), (f), and (g), of this Section offer to the applicant the alternative of basing the remainder of the flight path upon the conditions specified in the third segment discussed above.

The various conditions which have been specified in this Section to govern the configuration of the airplane assumed to exist in each of the various climb segments have been intended to reflect as closely as possible, the probable order in which a pilot would make changes in the airplane configuration in the actual case of engine failure or, are conservative in their nature in an effort to simplify the testing required to establish the flight path. Thus, for example, it is assumed that the pilot will do nothing except raise the landing gear for the length of time required for the gear fully to retract and it is also assumed that insofar as its effect upon the climbing performance is concerned the gear is down throughout this period. It is assumed that the pilot would make some adjustment of the propeller pitch control but that he would not initiate the operation of feathering prior to attaining a height of 50 feet which, in the limiting case permitted by the operating requirements, would also be the far end of the take-off runway; and, further, it is assumed that performance of the airplane remains that with the propeller idling until the feathering is complete. The take-off flap setting must be maintained throughout the determination of the take-off flight path.

Subject only to the restriction involving a value of $V_1$ less than $V_2$ which is covered by Item (d) of this Section and has been discussed in Section 04.75320-T above, each of these segments of the take-off flight path may be separately established, one of them (Segment No. 3) has already been established in order to show compliance with CAR 04.7531-T(c). The extent and nature of the testing required to establish the others is substantially identical with that required for the third segment which has been discussed above.

04.7533-T - Landing Determination

The purpose of this Section is to specify a distance which is required from a point 50 feet above the take-off surface to land and bring the airplane to rest, which is at once representative of actual operating technique and may serve as the basis for the specification of a landing runway length within which a pilot of average skill may reasonably to expected to be able to land the airplane safely under the most adverse weather or other operating conditions likely to be encountered in the actual operation of the airplane.

The minimum approach speed of 1.3 $V_{s_0}$, contained in Item (a), is intended to provide a reasonable margin above the stalling speed. Items (b) and (e) are concerned primarily with the prevention of an attempt to place the airplane in contact with the runway surface at a very high speed in order to take advantage of the greater deceleration provided by most wheel brake installations than is available from the drag of the airplane while still airborne. Flight Engineering Report No. 1 covers an investigation undertaken to determine the effect of various factors which were considered in drafting this Section and indicates the critical dependence of the landing distance here defined upon the contact speed. Obviously it will defeat the purposes of this Section if a distance be obtained by making contact at so high a speed as to require an exceptional degree of skill on the part of the pilot, or to base a distance upon exceptionally favorable conditions such as wind or the nature of the surface of the runway, and for this reason Item (e) in this Section forbids this.

Items (c) and (d) are concerned primarily with the extent to which wheel brakes may be appropriately used in establishing this distance. Obviously, the distance will not be representative if, upon every attempt to measure it, the brakes are burned up or a set of tires ruined. Since this would not be done except in extreme emergency in actual operation, such use of brakes is therefore forbidden.

It should be noted also that compliance with Item (c) requires the establishment of a maximum recommended pressure by the manufacturer of the brakes and the installation of a measuring device by means of which the pressure actually used may be observed. It is recommended that a statement of the approved operating pressure be obtained from the manufacturer of the brakes and submitted as a part of the test program discussed under PROCEDURE TO BE FOLLOWED BY APPLICANT in INTRODUCTION. The measurement of this landing distance is most satisfactorily done by photographic means and the Civil Aeronautics Administration is equipped with such means. The field set-up for the use of this equipment and the equipment itself, as well as the method of reading and analyzing results, are covered by Flight Engineering Reports 4 and 8.

Tests to establish the landing distance must be conducted with the most forward c.g. position to be approved by the terms of the type certificate.

04.754-T - Flight Characteristics

The relation between flight characteristics and safety involves the level of skill and the scope, character, and intensity of attention required on the part



5-20767

of the pilot to fly the airplane at all. It is theoretically possible to design an airplane which cannot be flown by a single pilot because, for example, he may not have enough strength, or alternatively a sufficiently delicate touch, to operate the controls or there may be so many necessary operations that he cannot, within the required time, perform them all. The purpose of the requirements contained in this and succeeding sections is to insure that a pilot or any appropriate crew may operate the airplane with enough margin of comfort that the performance of the airplane which has been covered by the preceding requirements may be realized and a reasonable level of safety maintained.

The succeeding Sections cover only the obviously more important of the flight characteristics under what have been agreed to be critical or representative flight regimes. It is the purpose of the first sentence of this Section to cover all those which have not been and probably cannot be anticipated for all airplanes and therefore covered by specific requirements. The requirements of the succeeding Sections will in most cases indicate what are considered to be the critical loading conditions, and, assuming the airplane to be found in compliance with those requirements at those loading conditions, no investigation of other loading conditions will ordinarily be required.

<u>04.7540-T - Controllability and Maneuverability</u>

The purposes of the first sentence of this Section are considered to be obvious from a reading of the text. Ordinarily no specific flight tests will be required to demonstrate compliance with its terms except for the following:

1. Those conditions normally encountered in the event of the sudden failure of any engine.

2. The establishment of the maximum tolerable cross component of wind velocity during take-off or during approach and landing.

   The former of these must be investigated with the airplane in the take-off configuration and at the maximum take-off weight authorized for sea level (see 04.750-T(a), (b), and 04.752-T), and will require the following specific demonstrations.

   (a) A demonstration that it is possible to recover to straight flight at the same speed with the wings level after any one engine is rendered suddenly inoperative during steady flight at best angle of climb speed or 120% of $V_{S1}$ (see CAR 04.7511-T) whichever the applicant shall select, while drawing take-off or maximum available power on the operating engine(s) with the landing gear retracted and the airplane loaded at the rearmost center of gravity. The rudder pedal force required to maintain straight flight shall not exceed 180 pounds.

   (b) A demonstration that it is possible to execute 15 degree banked turns with or against the inoperative engine starting from steady flight at 140% of $V_{S1}$ with one engine inoperative, the inoperative propeller operating in low pitch, maximum except take-off power on the operating engine(s), landing gear extended, wing flaps in the landing position, and with the airplane loaded at rearmost center of gravity.

(c) In order to demonstrate that the rudder will not lock or become heavily over-balanced in the fully deflected position at moderate angles of yaw, the airplane shall also be investigated for the effect of executing sudden changes in heading, as read by means of the directional gyro while holding the wings level, in gradually increasing increments until a maximum of 15 degrees has been reached or dangerous airplane characteristics encountered. This investigation shall be conducted at 140% of $V_{s_1}$ with one engine inoperative, the inoperative propeller feathered, maximum except take-off power on the operating engine(s), landing gear retracted, and the wing flaps in the condition used in the determination of the maximum one engine inoperative operating altitude (see CAR 04.7513-T).

The requirements of CAR 61.7122(c) and CAR 61.7123(b) make necessary the establishment of a maximum tolerable cross component of wing velocity beyond which take-off or landing upon a given runway becomes unsafe or impossible. The magnitude of this maximum cross-wind velocity depends greatly upon the controllability of the airplane either in the air or on the ground or both. It will, therefore, be required that the applicant state a maximum tolerable velocity for the particular airplane and demonstrate by means of at least three take-offs and three landings in cross wind velocities equal to or in excess of that selected that the airplane is safely controllable. The velocity so selected will then become a part of the operating limitations for the airplane.

The second sentence of this Section concerns itself with those changes in flap position and/or power which are likely to be encountered during an approach for landing when it becomes necessary to go around for another attempt at landing. Its purpose is to make any of these changes possible, assuming the pilot to find it necessary to devote at least one hand to the initiation of the desired operation, without being over-powered by the primary airplane controls. It aims at a design such that no excessive change in trim results from the application or removal of power or the extension or retraction of wing flaps. Compliance with its terms also requires that the relation of control force to speed be such that reasonable changes in speed may be made without encountering very high control forces. Compliance must be demonstrated starting with the landing gear in a position appropriate to the initial flap position; i.e., when flaps are up initially, the landing gear must be up and with flaps initially down, the landing gear must be down.

The third sentence of this Section is also concerned with the eventuality of going around during an approach for landing in which event it would be obviously desirable to be able to retract the wing flaps quickly and automatically at such a rate that if power be applied simultaneously with the initiation of flap retraction no altitude would be lost. The design feature involved with this requirement is obviously the rate of flap retraction. Compliance must be demonstrated with the landing gear extended.

## 04.7541-T - Trim

The essential purpose of trimming is to relieve the pilot of the necessity to apply continuously one or more control forces in order to maintain a given steady flight condition. It is the purpose of this Section to require that it be possible to trim the airplane completely for any flight condition which it is reasonable to assume will be maintained steadily for any appreciable time. The actual requirements are believed to be quite clearly stated by the text. Flight tests will, of course, be required to demonstrate compliance.

All "conditions of operation consistent with the intended use of the airplane" under which Item (a) of this Section requires lateral and directional trim which were foreseen at the time the regulation was originally written, are contained in Items (b), (c), and (d) of the Section. As a convenience in testing, it will be acceptable to interpret "best rate of climb speed" as 1.4 $V_{s1}$. There is also no apparent need that lateral and directional trim exist at the high speed when longitudinal trim is required by Item (b) at 90 percent of this speed only, and therefore lateral and directional trim at 90 percent of the high speed will also be considered satisfactory.

"Best rate of climb speed" in Item (b), (1), may also be interpreted as 1.4 $V_{s1}$.

Although not specifically stated in Item (c), the demonstration there required may be made with the inoperative propeller feathered.

## 04.7542-T - Stability

Stability is closely related to trim in that if stability is absent, trimming is impossible. It will be noted that in the succeeding Sections, a great deal more attention is devoted to longitudinal stability than to the lateral stability. This is regarded as merely a reflection of the fact that the longitudinal or elevator control is intimately involved in the establishment of center of gravity limits, which is always necessary, while the lateral characteristics ordinarily have negligible effect upon these. It will also be noted that, concerning longitudinal stability, the static stability is defined primarily in terms of the way the longitudinal control feels to the pilot, whereas the dynamic stability is specified in terms of the behavior which the airplane itself shall exhibit when certain specific things are done with the elevator control.

It has been attempted, in the succeeding Sections, to cover those specific flight regimes in which stability is considered essential. It is believed that these are critical in the sense that if the required stability obtain in these conditions it will probably also obtain in any other flight condition likely to be encountered with the airplane. If an airplane design be encountered for which this is not true it may be necessary to investigate other flight conditions.

## 04.75420-T - Static Longitudinal Stability

There are two basic purposes in requiring the static longitudinal stability which are defined by this Section.

The first of these is to require that, once the airplane has been trimmed, it will tend to maintain the trim speed in such manner as to require a conscious effort on the part of the pilot to depart from that speed, using forward pressure on the control column for an increase in speed and the reverse for a decrease. These forces must be such that departures in speed in either direction from the trim speed will require control column pressure that increase approximately proportionately as the speed departs from the trim speed. Static stability is specified in terms of "stick" forces because it is believed necessary and desirable to provide "feel" of the airplane for the pilot through this medium. Thus it may be seen that elimination of friction from the control system is an important factor that must be considered in connection with static stability. The accomplishment of this purpose is intended to provide safeguards against inadvertent stalls or inadvertent elevator control operation at excessive speeds, easy handling qualities during instrument flight and generally to hold to a minimum the amount of attention and skill required of a pilot during landings, take-offs and the other normal operating conditions. The second basic purpose is to make it possible to make such changes in speed as may be required to perform a maneuver without it being necessary to readjust the trim in order to relieve very high control forces which would otherwise be necessary.

The ideal relation of elevator control force to speed would be such that the control force required to maintain any speed should increase proportionally with the departure of speed from the trim speed and the magnitude of the force, at the extremes of possible or desirable departures, such as to be easily within the ability of the pilot to exert. Such ideal relationship is, however, very difficult to obtain in an actual airplane design particularly as the size of an airplane increases and the relative amount of power installed increases. Another difficulty is that there is friction in most airplane control systems which tends to blanket out the control forces involved when these are below a certain magnitude.

The requirement contained in this Section is, therefore, a compromise between what is desirable and what may readily be provided. Thus it requires not that the control forces involved be proportional to departures from trim speed throughout the range of attainable airplane speed, but only throughout a limited range of speed either side of the trim speed, and beyond this range that there be no reversal of the control forces. It also requires that the control system friction remain low enough that if the elevator control be released at any speed more than 10 MPH away from the trimmed speed, the control must move toward the trimmed position and the speed of the airplane must return when equilibrium is established to within 10 MPH of the trimmed speed. This in effect requires that the control force at any point within the range of speeds which may be attained with the airplane must exceed the force required to overcome the friction in the control system except within the range 10 MPH above or below the trim speed.



20767

The greatest difficulty likely to be encountered in attempting to demonstrate compliance with this requirement appears to be that for any condition involving the use of an appreciable amount of power the control force required to make substantial changes in speed tends to become vanishingly small, so small that appreciable changes in speed may occur without the change in the control force being perceptible to the pilot. This seems especially likely to be true if the control surfaces have been so designed that without power the control forces required to produce necessary changes in speed do not become excessive. Figure No. 1 has been prepared to indicate graphically what is required in the way of static longitudinal stability characteristics.

Although not specifically covered by the Regulations, it is also desirable that motion of the control column exhibit substantially the same characteristics as are required of the control forces. That is, it should require forward displacement of the column to produce a speed in excess of the trimmed speed and vice versa; the required displacement should be approximately proportional to the departure from the trimmed speed produced; and there should be no reversal of the sense of the required displacement of the control.

## 04.754200-T - Specific Stability Conditions

The four specific flight conditions covered by this Section are those in which it is believed that static longitudinal stability is especially important. For each of these it has been attempted to select a trim speed believed to be reasonable and likely for the flight condition and to specify a range of speed over which it is considered essential that the pilot be able to depend upon the approximate proportionality of control force to departure from the trim speed to indicate to him the instantaneous speed at which the airplane is operating. Flight tests are required to demonstrate compliance with these requirements and the tests involve the actual measurement of the control forces.

## 04.75421-T - Dynamic Longitudinal Stability

During the discussion which preceded the adoption of the provisions of this Section, it seemed generally conceded by most that dynamic longitudinal instability was somewhat more an annoyance than a positive hazard. It was, however, considered to be sufficient of an annoyance to warrant eliminating it for any flight condition likely to be maintained for any appreciable time. Since the removal of power and the extension of flaps and/or landing gear ordinarily improve stability, no gliding flight condition is specified. If stability be found during the two flight conditions here specified, it will ordinarily be unnecessary to investigate any other.

The testing required to demonstrate compliance with this requirement must ordinarily be done at both extremes of the range of center of gravity and involves disturbing the airplane by means of the longitudinal control and thereafter observing the oscillation of the airspeed.

It should be noted that the regulation requires that: "The airplane shall not be dynamically unstable." In order to show compliance, therefore, it will be necessary that the test involve not less than three complete cycles, unless the motion be completely damped in fewer, in order to be sure that the amplitude of the oscillation is not increasing.

No specific tests are required for the short period oscillation to which the last sentence of this Section refers unless it be encountered in the course of the flying which must otherwise be done with the airplane.

## 04.75422-T - Directional and Lateral Static Stability

The purpose of this requirement is to insure that the airplane shall behave normally if disturbed in roll or yaw. Although no real motion of the airplane involving roll is possible without yaw also being involved, and vice-versa, it is convenient to investigate the rolling and yawing stability separately and this is done in the testing required to show compliance with this requirement.

In the case of directional stability, the heading of the airplane is altered approximately 20 degrees by means of the rudder, the wings held level by means of the ailerons and the rudder released. The airplane is considered to comply if the resulting skid diminishes. In the case of lateral stability the airplane is rolled approximately 20 degrees by means of the ailerons, the heading maintained by means of the rudder and elevator and the ailerons released. The airplane is considered to comply if the angle of bank diminishes. Very little difficulty has ever been encountered in any airplane in showing compliance with this requirement.

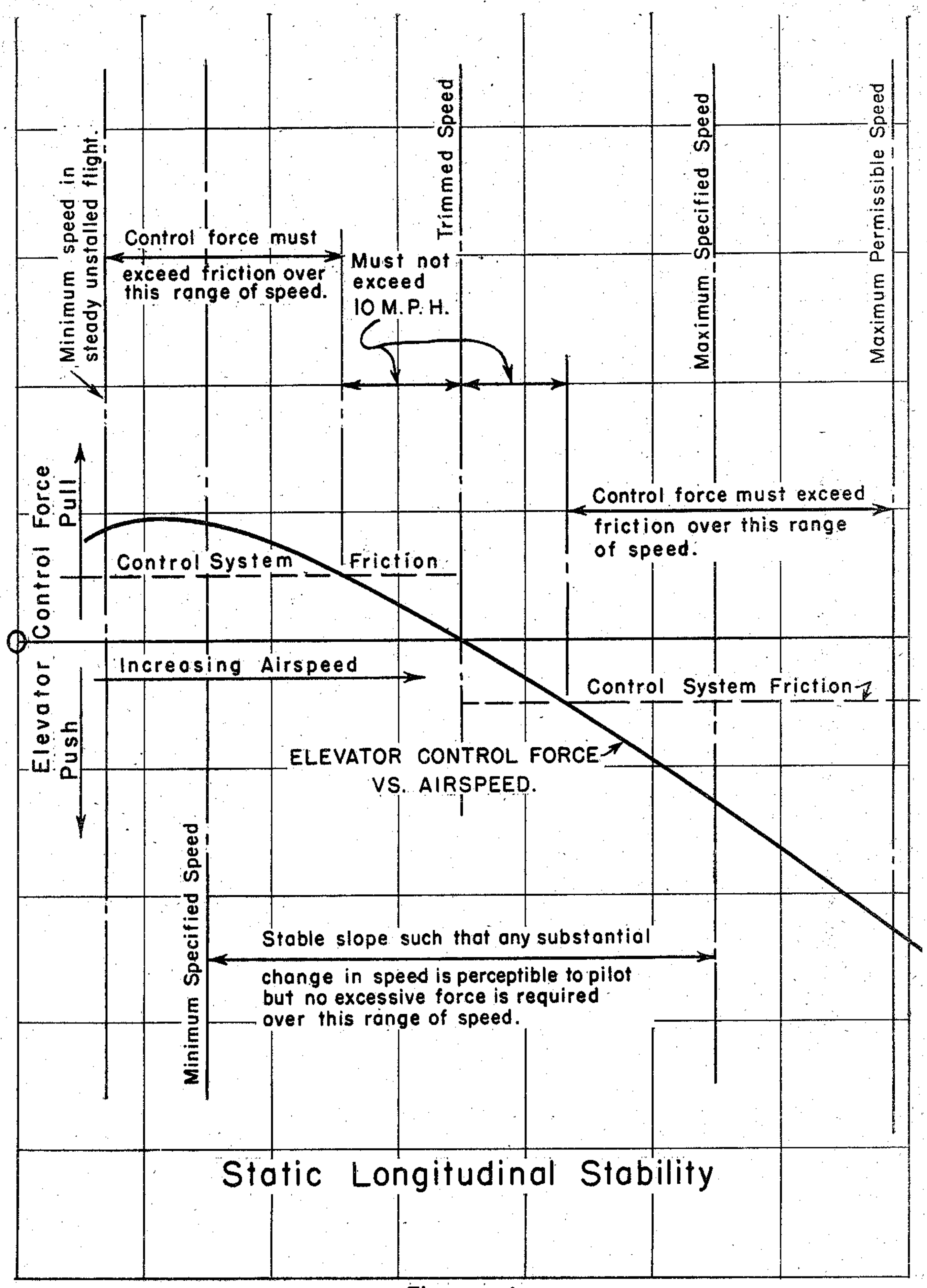
## 04.7543-T - Stalling

The basic purpose of this Section is to require that in any stall likely to be encountered inadvertently, the first response of the airplane shall be a downward pitching motion not a sudden rolling motion; i.e., it is intended to prohibit tip stalling. The testing required to demonstrate compliance with this requirement is specifically described in the text of the Section itself. The attainment of compliance with this requirement would seem to require very careful attention to the probable spanwise distribution of maximum lift coefficient in the design of the wing, or, failing this, some modification of the wing which will tend to delay stalling near the wing tips until the stall has developed over the inboard portion of the wing.

The primary purpose of the last sentence in this Section is to insure that when stalled with one engine inoperative the airplane does not become uncontrollable or loose an excessive amount of altitude. The required flight demonstration must be made with the airplane trimmed at 1.4 $V_{s1}$, with flaps and landing gear retracted and the inoperative propeller idling in low pitch.



20767



Minimum speed in steady unstalled flight.
Control force must exceed friction over this range of speed.
Must not exceed 10 M.P.H.
Trimmed Speed
Maximum Specified Speed
Maximum Permissible Speed
Elevator Control Force
Pull
Push
Control force must exceed friction over this range of speed.
Control System Friction
Increasing Airspeed
Control System Friction
ELEVATOR CONTROL FORCE VS. AIRSPEED.
Minimum Specified Speed
Stable slope such that any substantial change in speed is perceptible to pilot but no excessive force is required over this range of speed.
O
Static Longitudinal Stability


Figure I.

## 04.755-T - Airplane Operating Manual

The primary purpose of this manual is to provide for the crew who will operate the airplane any information concerning the airplane considered by the Administrator essential to or likely to promote safety during such operation. This will ordinarily require a certain amount of descriptive material concerning those parts of the airplane directly operated or otherwise used by the crew, an understanding by them of the nature, location, and functioning of which is therefore essential. The manual should also contain, in order to serve this purpose, a description and chronological outline of the procedure to be followed by the crew during various phases of the operation, both "normal" and "emergency" in which special attention and emphasis should be given to any precaution which should be observed therein in the interest of safety. "Check lists" which list in chronological sequence the operations to be performed by each active crew member during each phase of the operation of the airplane appear likely to be very useful in this connection. Finally, to accomplish this purpose of the manual, it is ordinarily necessary to include all instructions covering loading the airplane necessary to insure that the operating limitations upon weight and c.g. position may be readily observed.

Another important purpose of the manual is to implement the operating requirements of CAR 61.712; i.e., to furnish a source for all the airplane information necessary to establish the limitations specified by those requirements as well as that necessary to enable the crew readily to operate the airplane within the limitations so established. This purpose requires the inclusion in the manual of all operating limitations peculiar to the airplane under any circumstance likely to be encountered during its life as well as information concerning each of the items of performance involved by CAR 61.712 as functions of weight, altitude, wind velocity, flap setting, etc., throughout the range of these variables for which it is desired by the applicant to provide; the point being that the scheduled operation of the airplane by an air carrier will be limited to values of all such variables within the range(s) covered by information available in the manual. This situation requires that the applicant consider the extent to which he wishes to limit the usefulness of the airplane subsequent to its certification as a type.

In serving the purposes which have been described above, it appears probable that the manual will be used by both flight and ground personnel. The complete convenience of each of these groups might dictate a different form and arrangement of the manual for use by each. In the interest of simplicity, however, and considering the relatively greater difficulty of the circumstances under which flight personnel may be called upon to use the manual, it is considered highly desirable that their convenience be served in the matter. It has been attempted to accomplish this in the preparation of the outline presented hereunder.

It is believed that the usefulness of the manual will bear some inverse relation to its physical bulk and to the extent of its complexity. It is therefore strongly recommended that great care be taken to prepare it in the simplest, most compact form consistent with the completeness and clarity of presentation of the necessary information. This will probably require careful editing of text and consideration of details of arrangement. It is believed that an 8" x 10½" size will probably be found most convenient and this size is recommended.

It is also recommended that durability be considered in selecting the materials involved in its reproduction and binding. Finally, it is suggested that consideration be also given to the likelihood of revisions and the manner in and ease with which this is to be accomplished.

There is presented hereunder an outline intended to indicate a scope and arrangement of the manual and a treatment of the necessary material which, it is believed, will best accomplish all of the purposes considered above. Its use is recommended:

Title Page

(This page should form a front cover and should contain the name of the airplane manufacturer, the model designation and the serial number of the airplane to which the manual applies. It should also bear the title "Airplane Operating Manual," and should provide for approval by the CAA by means of the signature of: Chief, Flight Engineering and Factory Inspection Division, and a place to record the date of such approval.)

Log of Revisions

(This page should take the form of a table in which to record for each revision an identifying symbol, a date, page numbers involved, initialing or signature by the representative of the CAA, and the date of such action.)

Contents

(That is, a table of contents. It is suggested that its usefulness will be greatly enhanced if it be confined to a single page.)

I. OPERATING LIMITATIONS

(The purpose of this section is merely to state the limitations without any explanation not necessary to an understanding of what they are.)

A. WEIGHT
(State range of take-off weight and landing weight approved. Also that weight in excess of maximum landing weight must be disposable fuel. State any other limitations on weight and if appropriate refer to LOADING INSTRUCTIONS, Section V.)

B. CENTER OF GRAVITY
(State all authorized c.g. limits. Refer to LOADING INSTRUCTIONS.)

C. POWER PLANT
(State all power plant limitations; i.e., MP, RPM, TIME, Cylinder head and barrel and oil temperatures, minimum fuel octane No., etc., as well as any limitation on RPM due to roughness,

vibration, tip speed, etc.; propeller pitch, cowl flap position(s), etc.)

D. SPEED
(State "Never Exceed" speed for all flap settings, "Level Flight or Climb" speed, minimum controllability speed with one engine inoperative, minimum speed at which airplane may be climbed with one engine inoperative, critical speed during take-off beyond which flight may be continued and below which power should be cut and the airplane stopped, minimum "approach" speed, and any other limiting speed - all in true indicated airspeed.)

E. CREW
(State number and identify members of minimum crew necessary to safe operation.)

F. FLAPS
(State maximum flap extension approved for take-off, approach, landing as functions of weight or altitude if appropriate.)

G. TAXIING
(State any limitations on speed, power, wind direction, velocity during turns, cowl flap position, etc.)

H. WAVE HEIGHT (Seaplanes and flying boats only.)
(State maximum wave height approved for take-off and for landing.)

I. CRITICAL CROSS-WIND VELOCITY
(State critical or limiting value beyond which take-off or landing become dangerous.)

NOTE:
(Add any other items necessary.)

## II. <u>OPERATING PROCEDURES</u>

(This Section of the manual should contain information, peculiar to the airplane, concerning the normal and emergency procedures necessary to their safe performance by the crew.)

| | |
|---|---|
| A. START AND WARM UP ENGINES<br>B. TAXI<br>C. TAKE-OFF<br>D. APPROACH<br>E. LAND | (Outline normal procedure for each noting any special precautions in the interest of safety. Include check list for each crew member for each operation. Describe or refer to procedure in any emergency likely to occur in each.) |

F. ONE ENGINE INOPERATIVE
(Outline procedure to be used in event of engine failure during (a) take-off and (b) cruising flight including recommended speeds, trims, operation of remaining engine(s), propeller feathering, etc.)

G. PROPELLER FEATHERING
(Outline any necessary or desirable procedure to be followed.)

H. FUEL DUMPING
(Outline procedure including speeds, power, etc.)

I. CONTROL SYSTEM LOCKS

J. FLAP CONTROL

K. AUXILIARY POWER PLANT
(Describe procedure for starting and operating.)

L. FIRE EXTINGUISHING EQUIPMENT
(Outline procedure to be used in event of fire in various parts of airplane.)

M. DE-ICERS (Wing, Tail, Propeller, and Carburetor.)

N. WINDSHIELD CLEANERS AND DE-ICERS

O. LANDING GEAR

P. AUTOMATIC PILOT

Q. EMERGENCIES
(Outline any methods by means of which wing flaps, landing gear, etc., may be operated in event of failure of primary systems.)

NOTE:
Add any other item(s) necessary.

PERFORMANCE INFORMATION

(This Section should contain all the performance information necessary to implement the operating requirements of CAR 61.712 and safely to operate the airplane.)

A. ENGINE POWER CURVE
(A copy of the engine manufacturer's standard chart of BHP vs. MP @ RPM and BHP vs. Altitude @ RPM and @ MP.)

B. AIRSPEED CALIBRATION
(A plot of TIAS vs. IAS @ various flap positions, preferably on one page.)

C. STALLING SPEEDS
(A table or diagram of true indicated stalling speeds at various weights at all authorized flap settings, power off.)

D. CLIMB
1. Take-Off ) (A diagram of Climb vs. Altitude at Weight plus the
2. Enroute ) climbing air speed vs. altitude for each airplane
3. Approach ) configuration in standard air throughout the range
4. Landing ) of weight and altitude for which the airplane is certificated.)

E. TAKE-OFF
1. Accelerate-Stop Distance
(That is, the distance required to accelerate to the minimum speed for control with one engine inoperative and stop. A diagram showing Distance vs. Altitude at Weight throughout the range of Altitude h. and weight W. for which the airplane is certificated for take-off.)

2. Flight Path.
(That is, the take-off flight path specified by CAR 04.75321-T (a), (b), (d), (e), (f), and (g), as a function of weight and altitude throughout the range of each for which the airplane is certificated for take-off. It is suggested that this can probably be done most conveniently by preparing a diagram to scale on rectangular graph paper showing for each of several altitudes the flight path for each of several weights from the minimum to the maximum for the particular altitude.)

F. LANDING
(That is, the distance required by CAR 04.7533-T. A diagram showing Distance vs. Altitude at Weight and Wind Velocity throughout the range of altitude and weight for which the airplane is certificated for landing.) (See Figure No. 9 of Flight Engineering Report No. 13.)

G. RANGE
(To be supplied at a later date.)

IV. <u>GENERAL ARRANGEMENT</u>

(This Section should contain all descriptive material covering those parts of the airplane with which operating personnel should be especially familiar for safe operation or in the event of emergency.)

A. THREE-VIEW DRAWING
(A small three-view (not in excess of $10\frac{1}{2}$" x 11" x 22") showing the principal external dimensions of the airplane including propeller diameter and engine nacelle spacing and diameter.)

B. DESIGN CHARACTERISTICS
(A table of the principal design characteristics such as dimensions, wing and control surface areas, control surface movements, airfoil sections, dihedral, taper, sweepback, etc.)

C. ENGINE ACCESSORIES
(A brief description including carburetor make and model.)

D. FUEL SYSTEM )
E. OIL SYSTEM )
F. ELECTRICAL SYSTEM )
(A brief description of the operation of each plus a diagram of each.)

G. HYDRAULIC SYSTEM

H. CONTROL SYSTEM

I. AUXILIARY POWER PLANT

J. EMERGENCY EXITS
(A description, diagram showing location, and instructions for use.)

K. HULL COMPARTMENTATION (Flying Boats Only.)

L. EMERGENCY EQUIPMENT
(Description, location, instructions for use.)

V. LOADING INSTRUCTIONS

(This Section should include all instructions and information necessary so to load the airplane as to keep it within the operating limitations governing weight and c.g. location.)

A. CABIN ARRANGEMENT
(A diagram, approximately to scale, identifying and showing the location of each item of disposable load.)

B. LOADING SCHEDULE

C. INSTRUCTIONS
(Adequate instructions for the use of the loading schedule.)

## SCHEDULED OPERATION (CAR 40. and 61.)

### 40.2 - Passenger Minimum Requirements

This Section of the Regulations is intended to accomplish two basic purposes. The first of these is to require that any airplane, which has been certificated as a type in the Transport Category, must, in order to be eligible for use in scheduled air carrier operation, comply with the operating rules set forth in Section 61.712 over each route to be flown by the airplane. That this be required is implicit in the entire idea behind the Transport Category as explained in the INTRODUCTION.

The second purpose is to establish a time table of effectiveness of the Transport Category requirements which will permit the gradual conversion of scheduled air carrier operation from the use of airplanes not certificated in the Transport Category to those which have been. For this purpose, three separate cases are envisioned by this requirement:

1. New type airplanes which have never been previously, but are to be used in scheduled operation. This is covered by Item (a) of the Section which requires that any such type which shall have been certificated as a type after June 30, 1942, must, in order to be eligible for use in scheduled operation, have been certificated in the Transport Category.

2. Individual airplanes, of a type certificated prior to June 30, 1942, which type has been approved prior to that date for use in scheduled operation, which are introduced into scheduled operation after December 31, 1944. Item (c) requires that such individual airplanes must be certificated in the Transport Category and must be shown capable of complying with the operating rules of Section 61.712 in order to be eligible for use in scheduled operation. Practically, this means that the type must be shown to comply with the Transport Category requirements.

3. Airplanes maintained in scheduled operation after December 31, 1947. Item (d) requires that such airplanes be certificated in the Transport Category in order to be eligible.

The dates involved in Items (c) and (d) have been advanced since the original adoption of this Section because of interference by the war with possible replacement schedules. The original dates were 1941 and 1945 respectively.

<u>61.712 - Operating Limitations upon Airplanes Certificated Under Transport Category Requirements</u>

It may have been noted that the requirements of Part 04 of the Civil Air Regulations are such as to necessitate the determination, as a part of the type certification, of various items of the performance of the airplane. In order to complete the fundamental idea involved in the entire set of requirements, it is necessary to state a relation which shall exist between the dimensions involved in this performance and the dimensions of the route over which the airplane is to be operated. The purpose of this and succeeding sections is to state this relation. The nature of the relation is such as to impose a set of limitations upon the weight at which the airplane may be taken off in either direction on any runway at any weight for any trip over any route under any wind condition which it is desired by the applicant to consider.

The deviations which are contemplated by the first paragraph of this section are intended, as stated, to apply only to cases in which the detailed relation hereafter specified is not necessary in order to provide safety in operation. The only case of this kind, which was visualized during the discussion preceding the writing and adoption of these regulations, was that of an airport situated in mountainous terrain such that beyond the end of a take-off runway the terrain dropped sharply and appreciably below the level of the airport.



5-20767

In such case, it was argued, it were safe to permit take-off at an airplane weight such that, in the event of engine failure, a loss of altitude beyond the end of the runway might be experienced. The intent of this Section is, however, that the deviation be authorized only for such specific cases and that the burden of proof that the application of the regulations is not necessary shall rest with the applicant for the deviation.

The purpose of the second paragraph of this Section is to make provision for the fact that it is impracticable to measure the performance of the airplane during the type certification for every conceivable combination of those variables such as weight, altitude, wind velocity, etc., as may effect that performance in actual operation. Also, for the fact that all of the alternative pieces of equipment which may subsequently be installed in the airplane such as propellers, engines, etc., which also effect the performance cannot be anticipated and systematically investigated during type certification. The former of these two difficulties can largely be met during the type certification by so selecting weights and altitudes, for example, for which tests are to be conducted as to cover with reasonable accuracy the entire range of these over which the airplane is to be operated and such information will ordinarily be found in the Operating Manual required by CAR 04.755-T (See, also, INTRODUCTION.)

In the case of the second set of difficulties, there are many cases in which a calculation of the effect of the substitution, for example, of one propeller for another may be within the limits of precision with which the performance can be measured by direct testing. It is the intent of this requirement that such cases shall be substantiated by such calculation rather than to require a further direct measurement of the performance involved. It is recommended, in all such cases, that the applicant submit, with his application for approval of any change in the airplane, a proposal of the means by which he intends to establish the performance of the altered airplane.

61.7121 - General Limitations

It is believed that the provisions of this Section are reasonably clearly expressed by the text. Item (a) merely reflects the practical impossibility of determining whether or not the airplane may be operated in a given case when information concerning its performance is not available, as well as the undesirability that the operation be undertaken unless this information is available to the operating personnel. (See 04.755-T.) Practically, in case it is desired to undertake such an operation, it will be necessary to establish the maximum take-off or landing weight at the altitude(s) involved either by further testing or by extrapolation of the information already present in the Operating Manual to the altitude involved.

61.7122 - Take-Off Limitations to Provide for Engine Failure

The purpose of this Section is to provide that take-offs shall be made only under conditions such that an engine failure may be suffered at any point along the runway of take-off and thereafter the airplane may either be brought safely to a stop on the runway or the take-off continued, clearing any possible obstacles to flight by certain minimum specified distances. The application of this Section, in addition to the information required to be contained in the Operating Manual specified in Section 04.755-T, requires the establishment of certain information concerning the dimensions of the airport. These are essentially the length of any runways to be used and the location and elevation above the surface of the runway of any obstacles to flight beyond the end of the runway from which latter it must be decided the flight path to be followed by the airplane in the event of engine failure and the election of the pilot to continue the take-off. By combining the two sets of appropriate information; i.e., the dimensions involved in the take-off flight path and those of the runway and terrain beyond its end, a showing must be made that, at the weight which it is proposed to carry during the take-off, compliance with the requirements of Items (a) and (b) of this Section is shown.

Although it seems probable that turning flight involving even so slight an angle of bank as the 15 degrees here specified would reduce the climbing performance of the airplane and therefore alter the flight paths which will be contained in the Airplane Operating Manual, no information is available at this time concerning the magnitude of this effect, and until such information can be obtained it will be satisfactory to assume that the rate of climb remains unchanged; i.e., that the slope of the flight path, when viewed in side elevation, remains the same as if the flight path were parallel to the plane of projection.

The problem of correction of the performance of the airplane for the effects of runway gradient is a very difficult one because it is more unlikely that the distribution of gradient along the runway will be identical from runway to runway or from airport to airport. The effect of a uniform grade upon the accelerate-stop distance and the landing flight path is considered in Appendix III of Flight Engineering Report No. 5, which indicates that the magnitude of the effect may be appreciable.

The effect of wind upon the maximum weight which may be taken off from a given airport in compliance with the requirements of this Section is two-fold. First, the wind velocity component along the runway of take-off, if a head-wind velocity will, at a given airplane weight, reduce the distance involved in the take-off flight path to attain a given height and will thus permit taking off on a shorter runway than in a calm, or, conversely, its effect is to increase the weight which may be taken off upon a given runway. The magnitude of this effect is discussed in Flight Engineering Reports 5 and 7, and it should be noted that this Section permits consideration of only 50 percent of the actual wind velocity component along the runway.

The second of these effects is that the wind velocity and direction will determine the runway which must be used. This is due to the inherent difficulty involved in making a take-off in a cross wind. In order to take off the maximum weight at a given airport, the take-off must be made upon the longest runway in all cases where the cross wind velocity component does not exceed the critical value which will have been determined in showing compliance with the requirements of CAR 04.7540-T and, when this velocity be exceeded, upon the runway nearest the wind direction which does not produce a critical cross wind component upon this latter runway.

It may be seen that each of these effects involves both wind velocity and direction and that, in order to determine the maximum weight which may be taken off a given airport under any condition of wind, it is necessary that an analysis be made of the effect of winds of any velocity blowing in any direction. Figure II, and the text of Flight Engineering Report No. 13, illustrate a method by means of which this may be accomplished. It should be noted that the diagram assumes a maximum tolerable cross wind velocity component of one MPH. This is a convenient figure no matter what the actual critical velocity may be, for the reason that results read from such a diagram may be multiplied by the actual critical velocity. These diagrams postulate the operating procedure which is discussed above and in the text of the referenced report and they give the basic data by means of which the maximum weights which may be taken off for any runway when the wind conditions are such as to make the use of the runway necessary.

From all of the above, it appears that the minimum information concerning each airport which would show compliance with these take-off limitations would be a contour map of the airport and the surrounding terrain, plus a composite profile along each of the runways it is intended to use covering such width of terrain as may be involved in showing compliance with the lateral clearances specified by Item (b) of this Section, as well as the magnitude and distribution of any gradient along the runway plus a maximum take-off weight for each such runway obtained by the super position upon the profile for that runway of the appropriate flight path taken from the Operating Manual required by CAR 04.755-T corrected for the effect of any such gradient and for 50 percent of the axial component of any wind which it is desired to consider when using that particular runway. (See Flight Engineering Report No. 13.)

The simplest possible operation in compliance with the terms of this Section would appear to result from establishing a maximum take-off weight for each airport equal to the minimum such weight for any runway resulting from the analysis outlined immediately above.

## 61.7123 - Landing Distance Limitations

The purpose of this Section is to require that landings in scheduled operation shall be made only at such weights that at the point of landing a minimum relation between the dimensions of the landing flight path established by CAR 04.7533-T and the dimensions of the landing area which is defined herein shall exist. The practical application of this comparatively simple idea is complicated by the effect of wind velocity and direction upon the dimensions of the flight path and upon the direction in which it may be necessary to land. Item (a) concerns itself with the case of no wind and, in effect, requires that the airplane be so dispatched that the specified relation shall exist at the destination on at least one runway assuming there to be no wind at the time of arrival. Item (b) considers the possibility that, in spite of the provisions of Item (a), it may be necessary upon arrival to land on another and probably shorter runway because of the presence of a wind. This, of course, involves a critical lateral wind velocity component across the direction of the longest runway beyond which velocity a landing on that runway is considered unsafe. For any wind condition producing this critical lateral component there also exist lateral and/or axial components of wind velocity for each of the other runways. In order to land safely, therefore, it is necessary to select a runway across which the lateral component of wind velocity is below the critical value. The effect of the axial component along this runway is to shorten the landing distance of the airplane and, therefore, to permit meeting the specified relation between the dimensions of the flight path and those of the airport with a shorter runway length. The purpose of Item (b) is to require that the specified relation shall exist for any runway upon which it may be necessary to land when the dimensions of the flight path have been corrected by 50 percent of the actual effect of the axial wind velocity component which will exist. A graphical method by means of which to establish the variation of lateral and axial wind velocity components for all runways in terms of total wind velocity and direction is contained in Figures 2, 3, and 4, of Flight Engineering Report No. 5.

Item (c) is intended to provide an alternative to the requirement that the provisions of Items (a) and (b) be met at the intended destination which involves consideration of alternative fields and requires that if the provisions of Item (b) cannot be met at the time of arrival at the destination, the airplane must proceed to the alternate where they can be met.

It appears that the minimum information concerning each destination or necessarily considered alternate which must be submitted by the applicant to show compliance with the requirements of this Section is a critical cross wind component plus an analysis such as is here suggested of the effect of variations of wind velocity and direction upon the cross wind velocity component and axial velocity component for all of the runways involved plus, of course, the dimensions of the field showing the effective lengths of each of the runways (see Section 61.7124 below), or, alternatively (and this will permit the simplest actual operation), the establishment of a single maximum landing weight, for each airport, equal to the maximum permitted by the terms of this Section when landing in the most adverse direction on the shortest runway in no wind. (See Flight Engineering Report No. 13.)

## 61.71230 - Landing Distance at Alternate Fields

The purpose of this Section is merely to alter, in the case of alternate fields, the ratio which must exist between the effective length of the runway and the landing distance, as defined by CAR 04.7533-T. This has been done upon the basis that the improbability of finding it necessary to make use of an alternate destination is sufficiently great to warrant the taking of higher risks.

## 61.7124 - Definition of Effective Length of Landing Area

The purpose of this Section is to establish a definition of an effective length of runway for landing, which, when used as specified in CAR 61.7123, will provide that it be possible to approach and land while clearing all obstacles to flight by a vertical margin of at least 50 feet. The slope of the obstruction clearance line; namely, one to 20, was more or less arbitrarily



10767

selected but is not without a certain amount of rational fundation as is indicated by the discussion of this point in Flight Engineering Report No. 5.

The basis for the remainder of the provisions of this Section is believed to be clearly indicated by the text. It will, of course, be necessary to survey any landing area in which it is proposed to show compliance with the terms of CAR 61.7123 and it is suggested that a diagram such as has been recommended in the discussion of Section 61.7122 above will also prove to be the most convenient form in which to present the results of the survey here required.

61.7125 - En route Limitations

The basic purpose of this Section is to require that the airplane be operated at such weights that, in the event of engine failure at any point along any route over which it may be dispatched, it shall be possible to continue either to the intended destination or to a destination such that the landing distance limitations specified in CAR 61.7123 are equaled or bettered; in short, to prevent the necessity of a forced landing under dangerous conditions. It is by no means clear at this time that the rates of climb which are involved in the maximum one engine inoperative operating altitude as defined in Section 04.7513-T are actually adequate to accomplish this purpose. Compliance with the terms of this section does, however, insure a minimum risk which is consistent from airplane to airplane. The practical effect of this as of all the preceding Sections is to limit the take-off weight.

It appears that the minimum information concerning a route to be flown which must be submitted in order to show compliance with the requirements of this Section, is a composite profile along the centerline of the route representing the terrain contained within the ten miles either side of that centerline, plus a plot upon this profile of the maximum one engine inoperative operating altitude corresponding with the take-off weight which it is proposed to use reduced by the weight of fuel consumed in reaching any point along the route.

## TABLE OF REFERENCES


1. Type Inspection Report, Form ACA 283

2. FLIGHT ENGINEERING REPORT NO. 1
   "Investigation of the Landing Distance Required by CAR 04.7503 for a Typical Airplane"

3. FLIGHT ENGINEERING REPORT NO. 3
   "Airplane Climb Performance - General Discussion, and Corrections for Variations in Atmospheric Conditions, Engine Horsepower, and Airplane Weight"

4. FLIGHT ENGINEERING REPORT NO. 4
   "CAA Equipment for Recording Airplane Take-Off and Landing Characteristics"

5. FLIGHT ENGINEERING REPORT NO. 5
   "A Proposed Rational Method to Specify the Basic Dimensions of Airports in Terms of the Characteristics of Airplanes to be Operated Safely Therein."

6. FLIGHT ENGINEERING REPORT NO. 7
   "Determination of the Take-Off Flight Path Defined by CAR 04.7532-T for the DC-3-S1C3G Airplane - Including a Method to Correct Test Data to Standard Conditions"

7. FLIGHT ENGINEERING REPORT NO. 8
   "C.A.A. Equipment for Recording Airplane Take-Off and Landing Characteristics - Using Two Fixed Position Cameras"

8. FLIGHT ENGINEERING REPORT NO. 9
   "A Study to Determine the Maximum Weights Permitted by the Transport Category Requirements for the Douglas DC-3 Airplane"

9. FLIGHT ENGINEERING REPORT NO. 10
   "Effect of Airplane Weight upon Rate of Climb"

10. FLIGHT ENGINEERING REPORT NO. 13
    "The Application of the Transport Category Operating Rules to a Representative Route Flown by the Douglas DC-3 Airplane"